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Non-Anatomical Reconstruction of Chronic Posterolateral Corner Knee Injuries versus Anatomic Reconstruction Techniques: An Updated Systematic Review Reflecting the 2019 Expert Consensus Statement

Running Title: Chronic PLC Knee Injury Surgical Treatment

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Non-Anatomical Reconstruction of Chronic Posterolateral Corner Knee Injuries Show Failure Rates from 0% to 36% versus 4.3% to 24.2% for Anatomic Reconstruction Techniques: An Updated Systematic Review Reflecting the 2019 Expert Consensus Statement
Abstract

Objective: To review and update the literature regarding outcomes following surgical management of chronic, grade III posterolateral corner (PLC) injuries, with an emphasis on estimating failure rate based upon objective parameters in light of the 2019 expert consensus, while secondarily comparing the failure rates of anatomic versus nonanatomic reconstruction techniques.

Methods: A literature search was performed using PubMed, Embase, MEDLINE and Cochrane Library databases. Inclusion criteria consisted of level I-IV human clinical studies reporting subjective and objective outcomes in patients following surgical management for chronic (> 6 weeks from injury) grade III PLC injuries, with a minimum two-year follow-up. The criterion for objective surgical failure was based on post-operative varus stress radiographs and defined as side-to-side difference of 3 mm or more of lateral gapping.

Results: A total of 6 studies, consisting of 10 separate cohorts encompassing a total of 230 patients, were identified. PLC reconstruction was performed in all cohorts, with 80% (n = 8/10) of these cohorts utilizing an anatomic reconstruction technique. A failure rate ranging from 4.3% to 36% was found. Subgroup analysis revealed a failure rate of 4.3% to 24.2% for anatomic reconstruction techniques, whereas a 0% to 36% failure rate was found for non-anatomic reconstruction. Arthrofibrosis was the most common complication (range, 0% - 12.1%) following surgery. 0% to 8% of patients required a revision PLC surgery.
Conclusion: PLC reconstruction yields a wide variability in failure rates according to side-to-side difference of 3 mm or more of lateral gapping on post-operative varus stress radiographs, with low revision rates following anatomic and nonanatomic reconstruction techniques.

Level of Evidence: IV; Systematic Review of Level III and IV studies.

Keywords: Posterolateral corner, Knee, Fibular Collateral Ligament, Popliteus Tendon, and Popliteofibular Ligament, Anatomic Reconstruction

What is already known?
- The 2019 expert consensus statement for surgical treatment of PLC injuries states that anatomical reconstruction should be performed due to improved clinical outcomes.

What are the new findings?
- Surgical reconstruction for chronic PLC injuries results in a failure rate ranging from 4.3% to 36% with a failure rate of 4.3% to 24.2% for anatomic reconstruction techniques and 0% to 36% for non-anatomic reconstruction.
- Arthrofibrosis was the most common complication (range, 0% - 12.1%) following surgery.
- 0% to 8% of patients required a revision PLC surgery.
Introduction

Recent investigations on posterolateral corner (PLC) injuries have resulted in increased injury recognition and improved diagnosis, yielding a greater incidence of PLC corner injuries reported in the literature. [1-3] Injuries to the PLC complex, composed of the fibular collateral ligament (FCL), popliteus tendon (PLT), and popliteofibular ligament; have been reported to comprise up to 16% of ligamentous knee injuries.[4] Posterolateral corner knee injuries are infrequently reported to occur in isolation, with concurrent injuries to the anterior cruciate ligament (ACL) and posterior cruciate ligament (PCL) reported to occur in up to 75% of cases.[5]

In the setting of grade I and II PLC injuries, conservative management is generally recommended. Conversely, grade III injuries have demonstrated unfavorable outcomes when treated conservatively, complicated by persistent instability and early onset osteoarthritis.[1, 2, 6-8] As a result, operative management is recommended for the treatment of grade III injuries.[2, 9] LaPrade et al. recently reported superior results utilizing an anatomical reconstruction when compared to non-anatomical techniques, such as primary repair or biceps femoris tenodesis.[10] [11-13] There have been an estimated 400 articles published relating to PLC injuries in the last decade.[14] Despite this recent increase in the reported incidence and management of PLC injuries, optimal surgical treatment remains controversial, especially in regard to the treatment of chronic, grade III injuries.

A systematic review of chronic PLC injuries by Moulton et. al in 2016, revealed substantial heterogeneity in outcome measures and surgical techniques across the literature.[1] Since then, in an effort to standardize the treatment approach and optimize the management of PLC injuries, an expert consensus statement was published in 2019 involving 27 international experts.[15]
Among several aspects, the expert group recommendations highlighted the importance of anatomic reconstruction of PLC tears, as well the use of stress radiographs as a tool to standardize objective post-operative assessment.[15] The purpose of this study was to review and update the literature regarding outcomes following surgical management of chronic, grade III PLC injuries, with an emphasis on estimating failure rate based upon objective parameters in light of the 2019 expert consensus, while secondarily comparing the failure rates of anatomic versus nonanatomic reconstruction techniques. We hypothesize that surgical management of chronic, grade III PLC injuries will yield low failure rates, with a higher rate of failure using nonanatomic reconstruction compared to anatomic reconstruction.

Methods

Search Strategy

A systematic review was conducted in accordance with the 2009 PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) statement.[16] Two authors (initials blinded for peer review) performed an independent search of the PubMed, Embase, MEDLINE and Cochrane Library databases for relevant literature published from inception to November 2022. The search strategy consisted of combinations of the following search terms and Boolean operators:

1. “posterolateral” AND “corner” AND (“knee” OR “knee joint” OR “joint”)
2. “posterolateral” AND “instability”
3. “multiligament” AND (“knee” OR “knee joint” OR “joint”)
4. “knee dislocation” OR (“knee” AND “dislocation”)


Eligibility Criteria

Inclusion criteria consisted of level I-IV human clinical studies reporting subjective and objective outcomes of patients who underwent surgical treatment for chronic (> 6 weeks from time of injury), grade III PLC injuries to the knee, with a minimum two-year follow-up. Only studies that reported the proportion of patients with lateral gapping deemed unacceptable, of ≥3 mm or more, were included. PLC injury was defined as a tear to either the FCL, PT, PFL, or any combination of these structures. Chronic injuries, defined in the systematic review by Moulton et al., were considered as injuries treated after 6 weeks from the time of injury.[1] Only articles written in English or those with English-language translation were included. For this study, a minimum delay of 6 weeks between the time of injury to surgery was used as inclusion criteria to define a chronic PLC injury as previously reported by Chahla et al.[2]

Exclusion criteria consisted of non-English language studies or those without English-language translation, studies with less than two-year mean follow-up, abstracts, biomechanical or laboratory studies, review articles, case reports, patients sustaining associated fracture-dislocations, surgical treatment preceded with external fixation, studies assessing multi-ligament knee injuries in which a separate cohort comprised of combined PLC injuries was not identified. Studies not reporting outcomes following surgical management were similarly excluded. Studies that reported duplicated patients were excluded.

Data Extraction

Following the literature search and removal of duplicate entries, two independent authors (initials blinded for peer review) performed an initial title and abstract screening, followed by full-text review. A third independent author (initials blinded for peer review) was assigned to
resolve any disagreements during the screening process, though none were encountered. All references cited in the studies included for final qualitative analysis were reconciled and reviewed to optimize identification of all relevant literature.

The following data was extracted from the selected studies: authors, article title, year of publication, level of evidence (as per Wright et al.)[14], study design, cohort demographics, mean duration and range of follow-up, duration from injury to surgery, injury characteristics, concomitant procedures, surgical technique details, patient-reported outcome (PRO) measures, return to work (RTW) and return to sport (RTS) metrics. Post-operative side-to-side differences in lateral compartment gapping on varus stress radiographs, reported complications, and re-operation rates were also collected. Mean values, standard deviation, and range were collected whenever available for all continuous numerical variables.

In their previous systematic review, Moulton et al.[1], defined failure as an objective International Knee Documentation Committee (IKDC) grade of C or D[17], American Medical Association (AMA) grade II or III[18], side-to-side difference of 4.0 mm or greater in lateral compartment gapping on varus stress radiograph,[19] or if the knee was reported as unstable when compared to the contralateral uninjured knee. However, these criteria are potentially not rigorous enough, because physical examination can be subjective and prior evidence demonstrates the FCL – the key structure in the PLC – failing with substantially lower thresholds of lateral gapping on varus stress radiographs.[19-22] Thus, as opposed to extracting success and failure rates by Moulton’s criteria, the pooled failure rate was estimated solely from the studies reporting on post-operative varus stress radiograph data, in consonance with the 2019 expert consensus recommendations.[15] Based on a recent biomechanical study by Gursoy et al.[23], we consider a side-to-side difference of 2.2 mm of lateral compartment gapping as indicative of
grade III fibular collateral ligament pathology. Nevertheless, upon examination of the included studies reporting on post-operative stress radiographs, the lowest cutoff value consistently used across studies was of 3 mm, which was ultimately established as the criterion for objective failure in this review.

Risk of Bias

A methodological quality assessment of the included studies was performed by two authors (initials blinded for peer review) to ensure bias was minimized using the Newcastle-Ottawa Scale (NOS) for studies of level I-III evidence and the National Institute of Health (NIH) Quality Assessment for level IV evidence studies. (Appendix Tables 1 and 2).

Data Analysis

Upon exploratory analysis, the eligible clinical studies included for final analysis were deemed to have high heterogeneity in terms of treatment arms, reporting of outcome measures, high risk of bias, and limited high-level evidence studies, thus data pooling was avoided. Box-and-whisker plots were created using Microsoft Excel version 16.63 (Microsoft Corp, Redmond, WA) to illustrate the mean outcome scores for studies that reported mean and standard deviation. Only outcome scores that had a minimum of three studies reporting the score were illustrated using the box-and-whisker plots.

Results

The initial search resulted in a total of 10,159 entries after duplicate removal. (Figure 1) Title and abstract screening resulted in 75 articles for full-text review, 36 of which met the
eligibility criteria and were included for final qualitative analysis. These 6 studies[24-29](consisting of 10 separate cohorts) were comprised of 3 level III studies[25-27, 30] and 3 level IV studies[24, 28, 29].

The studies included for final review yielded a combined 230 knees, with a mean patient age ranging from 27 to 38.9 years. Five studies reported the mean duration from the time of injury to surgical treatment of 7.8 to 15.3 months. Mean follow-up ranged from 24 to 51.2 months, as reported by 7 of the cohorts.

None of the included studies reported cases of isolated PLC injuries. Combined PLC and PCL injury was reported in 81.7% (n = 188/230) of all reported injuries. Combined PLC and ACL injury occurred in 16.1% (n = 37/230) of cases, while a combined PLC and bi-cruciate (ACL and PCL) injury were present in 2.2% (n = 5/230) of cases. (Table 1)

<table>
<thead>
<tr>
<th>Author (Year)</th>
<th>LOE</th>
<th>Patients, n</th>
<th>Mean Age (Range), y</th>
<th>Mean Time to Surgery (Range), d</th>
<th>Mean Follow-up (Range), y</th>
<th>Isolated PLC</th>
<th>PLC + ACL</th>
<th>PLC + PCL</th>
<th>PLC + ACL/PCL</th>
<th>Staged (n)</th>
<th>Surgical Technique (Reconstruction or Repair)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kim (&lt;40 degrees*, 2013)</td>
<td>IV</td>
<td>26</td>
<td>38.9</td>
<td>NR</td>
<td>NR</td>
<td>0</td>
<td>0</td>
<td>26</td>
<td>0</td>
<td>No</td>
<td>Reconstruction</td>
</tr>
<tr>
<td>Kim (40-50 degrees*, 2013)</td>
<td>IV</td>
<td>21</td>
<td>36.1</td>
<td>NR</td>
<td>NR</td>
<td>0</td>
<td>0</td>
<td>21</td>
<td>0</td>
<td>No</td>
<td>Reconstruction</td>
</tr>
<tr>
<td>Kim (&gt;50 degrees*, 2013)</td>
<td>IV</td>
<td>18</td>
<td>36.1</td>
<td>NR</td>
<td>NR</td>
<td>0</td>
<td>0</td>
<td>18</td>
<td>0</td>
<td>No</td>
<td>Reconstruction</td>
</tr>
<tr>
<td>Kim (2012)</td>
<td>III</td>
<td>23</td>
<td>36.4</td>
<td>7.8 (1-30)</td>
<td>24</td>
<td>0</td>
<td>23</td>
<td>0</td>
<td>0</td>
<td>No</td>
<td>Reconstruction</td>
</tr>
<tr>
<td>Kim (single bundle, 2011)</td>
<td>III</td>
<td>23</td>
<td>30.7</td>
<td>11.2 (7-39)</td>
<td>51.2 (24-70)</td>
<td>0</td>
<td>0</td>
<td>23</td>
<td>0</td>
<td>No</td>
<td>Reconstruction</td>
</tr>
<tr>
<td>Kim (double bundle, 2011)</td>
<td>III</td>
<td>19</td>
<td>31.3</td>
<td>12.7 (5-48)</td>
<td>44.5 (27-62)</td>
<td>0</td>
<td>0</td>
<td>19</td>
<td>0</td>
<td>No</td>
<td>Reconstruction</td>
</tr>
</tbody>
</table>
A PLC reconstruction was performed in all included studies. (Table 1) Of these, 80% (n = 8/10) of the cohorts described their technique as an anatomic reconstruction of PLC components. A non-anatomic reconstruction was reported in 20% (n = 2/10) of cohorts (Table 2).

The classic anatomy-based reconstruction described by LaPrade et al[12] was the technique of choice in Franciozi et al[24], although modified for the use of hamstring autograft. Kim et al[25-28] utilized an anatomy-based PLC reconstruction technique with a single tibialis posterior graft recreating the FCL, PLT, and PFL, with a strand of the graft overlying the anterior tibiofibular joint. Non-anatomic reconstructions included Larson’s fibular sling single-femoral tunnel technique in a study by Lee et al.[29], and rerouting of the biceps femoris tendon to the isometric point on the lateral epicondyle, as used in one cohort by Kim et al.[26]

Seventy percent (n = 7/10) of cohorts reported the use of an allograft and 30% (n = 3/10) reported the use of an autograft. (Table 2) The tibialis posterior tendon was used in all allograft
reconstructions. The most prevalent autograft sources were the hamstring tendon and biceps femoris tendon, both reported in 66.7% of autograft reconstructions (n = 2/3 cohorts). (Table 2) Screws were the most commonly reported implant used for graft fixation, used solely in 60% (n = 6/10 cohorts) of cohorts, or with the incorporation of anchors (3 cohorts), or a toothed washer (1 cohort) (Table 2).

Table 2. Characterization of PLC Surgical Technique utilized for each study

<table>
<thead>
<tr>
<th>Author (Year)</th>
<th>Repair or Reconstruction</th>
<th>One vs. Two-Tailed</th>
<th>Number of Grafts Used</th>
<th>Graft Source</th>
<th>Method of Fixation</th>
<th>Summary of Technique</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kim (&lt;40 degrees*, 2013)</td>
<td>Reconstruction</td>
<td>NR</td>
<td>1</td>
<td>Tibialis Posterior Allograft</td>
<td>Screws and/or Anchors</td>
<td>Anatomic reconstruction of FCL and PLT with a tibialis posterior allograft, including the tibia and using bioabsorbable screw fixation.</td>
</tr>
<tr>
<td>Kim (40-50 degrees*, 2013)</td>
<td>Reconstruction</td>
<td>Two</td>
<td>1</td>
<td>Tibialis Posterior Allograft</td>
<td>Screws and/or Anchors</td>
<td>Anatomic reconstruction of FCL and PLT with a tibialis posterior allograft, including the tibia and using bioabsorbable screw fixation.</td>
</tr>
<tr>
<td>Kim (&gt;50 degrees*, 2013)</td>
<td>Reconstruction</td>
<td>Two</td>
<td>1</td>
<td>Tibialis Posterior Allograft</td>
<td>Screws and/or Anchors</td>
<td>Anatomic reconstruction of FCL and PLT with a tibialis posterior allograft, including the tibia and using bioabsorbable screw fixation.</td>
</tr>
<tr>
<td>Kim (2012)</td>
<td>Reconstruction</td>
<td>Two</td>
<td>1</td>
<td>Tibialis Posterior Allograft</td>
<td>Screws</td>
<td>Anatomic reconstruction of FCL and PLT using a tibialis posterior allograft, including the tibia and secured with bioabsorbable screw fixation.</td>
</tr>
<tr>
<td>Kim (single bundle, 2011)</td>
<td>Reconstruction</td>
<td>NR</td>
<td>2</td>
<td>Tibialis Posterior Allograft</td>
<td>Screws</td>
<td>Anatomic reconstruction of FCL and PLT using a tibialis posterior allograft, including the tibia and secured with bioabsorbable screw fixation.</td>
</tr>
<tr>
<td>Kim (double bundle, 2011)</td>
<td>Reconstruction</td>
<td>NR</td>
<td>1</td>
<td>Tibialis Posterior Allograft</td>
<td>Screws</td>
<td>Anatomic reconstruction of FCL and PLT using a tibialis posterior allograft, including the tibia and secured with bioabsorbable screw fixation.</td>
</tr>
<tr>
<td>Kim (anatomic reconstruction, 2011)</td>
<td>Reconstruction</td>
<td>Two</td>
<td>1</td>
<td>Tibialis Posterior Allograft</td>
<td>Screws</td>
<td>Anatomic reconstruction of FCL and PLT using a tibialis posterior allograft, including the tibia and secured with bioabsorbable screw fixation.</td>
</tr>
<tr>
<td>Kim (rerouting biceps tendon, 2011)</td>
<td>Reconstruction</td>
<td>One</td>
<td>2</td>
<td>Biceps tendon Autograft</td>
<td>Screw and washer</td>
<td>Non-anatomic reconstruction technique of PFL, FCL with interference screw at the isometric point at the anterior and proximal margin of the lateral epicondyle, washer.</td>
</tr>
</tbody>
</table>
Lee (2015) Reconstruction One 1 Hamstring Autograft Screws Non-anatomic modified Larson’s technique using hamstring tendon secured with interference screw to a single femoral tunnel, with a fibular sling.

Legend: FCL: Fibular Collateral Ligament; PLT: Popliteus Tendon; LCL: Lateral Collateral Ligament; PFL: Popliteofibular Ligament; ITB: Iliotibial Band; BTB: Bone-Tendon-Bone

*, represents the degree of tibial external rotation at 90 degrees of knee flexion.

Outcomes

Patient-reported outcomes at final follow-up, as well as side-to-side differences on varus stress radiographic measurements, are reported in Table 3. Lysholm scores were reported in 9 cohorts (Figure 2), IKDC scores in 2 cohorts, and Tegner Activity scale in 2 cohorts.

By the aforementioned criterion, an overall failure rate ranging from 4.3% to 36% was observed. Subgroup analysis revealed a failure rate ranging from 4.3% to 24.2% for anatomic reconstruction techniques (here defined as reproducing the FCL, PT and PFL, and incorporating the tibia in the construct), versus a 0% to 36% failure rate for non-anatomic reconstruction.

Table 3. Outcomes

<table>
<thead>
<tr>
<th>Author (Year)</th>
<th>Mean Follow-up Lysholm Score (Range)</th>
<th>Mean Follow-up IKDC Score (Range)</th>
<th>Mean Follow-up Tegner Score (Range)</th>
<th>Post-operative SSD on Varus Stress Radiograph ≥ 3mm, % (n/total sample)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kim (&lt;40 degrees*, 2013)</td>
<td>85.8 (± 7.9)</td>
<td>NR</td>
<td>NR</td>
<td>15.4 (4/26)</td>
</tr>
<tr>
<td>Kim (40-50 degrees*, 2013)</td>
<td>88.7 (± 6.9)</td>
<td>NR</td>
<td>NR</td>
<td>23.8 (5/21)</td>
</tr>
<tr>
<td>Kim (&gt;50 degrees*, 2013)</td>
<td>84.1 (± 6.7)</td>
<td>NR</td>
<td>NR</td>
<td>16.7 (3/18)</td>
</tr>
<tr>
<td>Kim (2012)</td>
<td>90.1 (± 7)</td>
<td>NR</td>
<td>NR</td>
<td>8.7 (2/23)</td>
</tr>
<tr>
<td>Kim (single bundle, 2011)</td>
<td>85.7 (± 7.6)</td>
<td>NR</td>
<td>NR</td>
<td>4.3 (1/23)</td>
</tr>
<tr>
<td>Kim (double bundle, 2011)</td>
<td>87.7 (± 7.3)</td>
<td>NR</td>
<td>NR</td>
<td>5.3 (1/19)</td>
</tr>
<tr>
<td>Kim (anatomic reconstruction, 2011)</td>
<td>89.1 (± 1.4)</td>
<td>NR</td>
<td>NR</td>
<td>4.8 (1/21)</td>
</tr>
<tr>
<td>Kim (rerouting biceps tendon, 2011)</td>
<td>82.7 (± 2.0)</td>
<td>NR</td>
<td>NR</td>
<td>36 (9/25)</td>
</tr>
</tbody>
</table>
Franciozi (2019)  81.2 (48-100)  70.4 (35-100)  5.5 (2-10)  24.2 (8/33)
Lee (2015)  NR  79.6 (± 11.3)  5 (3-7)  0 (0/21)

Legend: IKDC: International Knee Documentation Committee; ADL: Activities of Daily Living; QoL: Quality of Life; NR: not reported; SSD: side-to-side difference

*, represents the degree of tibial external rotation at 90 degrees of knee flexion

Complications
Arthrofibrosis was the most common complication following surgery with a rate ranging from 0% to 12.1%, followed by cortical break at the fibular head requiring 6 additional weeks of immobilization which ranged from 0% to 4.8%. A range from 0% to 8% of patients required revision surgery. (Appendix Table 3)

Discussion
The most important finding of this study is that chronic PLC tears treated with reconstruction exhibited an overall failure rate ranging from 4.3% to 36% at a minimum 2-year follow-up as defined by objective post-operative residual varus laxity on stress radiographs. Additionally, subgroup analysis revealed that anatomical reconstruction exhibited a lower failure rate when compared to non-anatomical reconstruction by the same criterion. Our collation of the available literature revealed that few chronic PLC tears occur in isolation, and the most common association is with PCL tears (81.7%). In consonance with the recent PLC expert consensus recommendations, anatomic reconstruction was found to be the current standard of management, as reported in 80% of the included cohorts.

Our results are in contrast with the findings of the previous systematic review by Moulton et al., which estimated the failure rate following surgical treatment of PLC injuries at 10%.
Specifically, Moulton et al. evaluated a total of 15 studies (456 patients) published prior to September 2014 but used rather lenient criteria to define treatment failure. Previous investigations support low sensitivity of physical examination in the assessment of PLC tears, with Bonadio et al. reporting under 60% of correspondence with intraoperative identification of FLC tears.[30] Not coincidentally, adherence to stress radiographs as a means to objectively assess postoperative PLC reconstruction stability. The criterion for post-operative failure upon varus stress radiograph utilized by Moulton et al., however, was of 4.0 mm, which would be in fact indicative of complete PLC insufficiency according to the diagnostic thresholds defined in the study by LaPrade et al on varus stress radiographic changes following sequential transection of PLC structures.[19] Subsequent biomechanical studies have further demonstrated that asymmetries in lateral gapping of as little as 2.0 to 2.2 mm are sensitive to tears of the FCL, which is well-established as the primary varus stabilizer of the knee.[22, 23] Therefore, we advocate that future investigations strive to standardize the definition of surgical success and failure always according to objective radiographic measurement, using 2.2 mm as a cutoff value. Although the available data set in this review did not allow us to consistently apply this value during extraction, the two studies that did make supplementary data available amounted to a 20% failure rate among 65 total patients using a 2.2 mm cutoff. These results suggest that prior literature likely underestimated failure rates following PLC reconstruction.

One aim of this systematic review was to identify and consolidate the different reconstruction techniques performed in the treatment of chronic, grade III PLC injuries. The PLC expert consensus statement recommended that mid-substance PLC injuries be treated with anatomic-based reconstruction, reserving primary repair only for bony avulsion injuries.[15] While we observed a substantial proportion (80%) of reconstruction techniques included in this
review reporting the utilization of an anatomic reconstruction, only one of the cohorts utilized LaPrade’s classic anatomic-based technique principles. Interestingly, a modification of the anatomic reconstruction technique was used as described by Franciozi et al.[31] to accommodate the use of a hamstring autograft, relying on the added length provided by the loop of a suspensory cortical fixation device on the anterior tibial cortex. This technique can potentially allow for increased adherence to the principles of an “anatomic technique” in countries or institutions where allografts are not widely available.

Anatomic reconstruction cohorts failed at a lower rate ranging from 4.3% to 24.2% compared to non-anatomic reconstruction cohorts which failed at a rate from 4.3% to 36%. Anatomical reconstruction has a well-established capability to restore native static stability of the knee in response to varus loading and external rotation torque in vitro.[32] Further biomechanical studies point to the shortcomings of non-anatomical reconstruction. Vezeridis et al.[33] demonstrated underconstrained knees at 90º of flexion with a fibular sling technique and Drenck et al. found that a fibular sling technique failed to restore external rotational stability of the native knee, which the addition of a tibial-based construct including the popliteus adequately restored.[10] While clinical studies of different techniques are still largely insufficient to provide data for direct comparisons between techniques, a case series by Yoon et al. revealed decreased varus external rotation laxity for anatomic PLC reconstruction relative to sling procedures on postoperative arthroscopic evaluation.[34]

The most common postoperative complication reported was arthrofibrosis, with 0% to 12.1% of patients reporting this complication. While early range of motion protocols have been associated with lower rates of postoperative arthrofibrosis and are widely emphasized in the expert consensus recommendations, further studies are warranted to best understand patient and
injury-specific variables associated with the development of arthrofibrosis in order to minimize this potential complication.[35]

This investigation is not without limitations. As the available literature on the treatment of chronic PLC tears is limited to observational, and in a large amount, to case series, the inherent selection and reporting biases also apply to our review. Furthermore, 176 of the 230 knees included in this review were from a single source (Kim et al.). Despite a number of studies reporting Lysholm, a statistical comparison across the different studies was precluded by heterogeneity in patient populations, surgical techniques, and injury patterns reported, and due to several non-comparative designs included. Despite the expert consensus statement[15] recognizing the value of postoperative varus stress radiographs to objectively assess the stability of reconstruction, most available studies still rely on less objective criteria to define “success” and “failure”.
Conclusion

PLC reconstruction yields a wide variability in failure rates according to side-to-side difference of 3 mm or more of lateral gapping on post-operative varus stress radiographs, with low revision rates following anatomic and nonanatomic reconstruction techniques.
References


Figure 1. PRISMA Flow diagram outlining the process of study selection.

Legend: PLC, posterolateral corner.

Figure 2. Box-and-whisker plot illustrating the mean postoperative Lysholm scores

Appendix

Appendix Table 1. Quality Assessment of the included studies by the Newcastle-Ottawa Scale (NOS). Each study was evaluated on three broad perspectives: the selection of study groups; the comparability of the groups; and the ascertainment of the outcomes measured. A star indicates that the study met the requirements for the characteristic in question. A maximum of nine stars can be awarded to each study.

<table>
<thead>
<tr>
<th>Study (Year)</th>
<th>Selection</th>
<th>Comparability</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Representativeness of treated cohort</td>
<td>Selection of comparative cohort</td>
<td>Ascertainment of treated cohort records</td>
</tr>
<tr>
<td>Kim (2012)</td>
<td>✭</td>
<td>✭</td>
<td>✭</td>
</tr>
<tr>
<td>Kim (2011)</td>
<td>✭</td>
<td>✭</td>
<td>✭</td>
</tr>
</tbody>
</table>

NIH Quality Assessment ✔
### Study (Year)

- **Was the research question or objective in this paper clearly stated?**
- **Was the study population clearly specified and defined?**
- **Was the participation rate of eligible persons at least 50%?**
- **Were all the subjects selected or recruited from the same or similar population?**
- **Was a sample size justification, power description, or variance and effect estimates provided?**
- **For the analyses in this paper, were the exposure(s) of interest measured prior to the outcome(s) being measured?**
- **Was the time frame sufficient so that one could reasonably expect to see an association between exposure and outcome if it existed?**
- **For participants that can vary in amount or level, did the study examine different levels of the exposure?**
- **Was the exposure measure (independent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?**
- **Was the exposure(s) assessed more than once over time?**
- **Were the outcome measures (dependent variables) clearly defined, valid, reliable, and implemented? Consistently across all study participants?**
- **Were the outcome assessors blinded to the exposure status of participants?**
- **Was loss to follow-up after baseline 20% or less?**
- **Were key potential confounding variables measured and adjusted statistically for their impact on the relationship between exposure(s) and outcome(s)?**
- **Summary Quality**

| Study (Year) | Was the research question or objective in this paper clearly stated? | Was the study population clearly specified and defined? | Was the participation rate of eligible persons at least 50%? | Were all the subjects selected or recruited from the same or similar population? | Was a sample size justification, power description, or variance and effect estimates provided? | For the analyses in this paper, were the exposure(s) of interest measured prior to the outcome(s) being measured? | Was the time frame sufficient so that one could reasonably expect to see an association between exposure and outcome if it existed? | For participants that can vary in amount or level, did the study examine different levels of the exposure? | Was the exposure measure (independent variables) clearly defined, valid, reliable, and implemented consistently across all study participants? | Were the outcome measures (dependent variables) clearly defined, valid, reliable, and implemented? Consistently across all study participants? | Were the outcome assessors blinded to the exposure status of participants? | Was loss to follow-up after baseline 20% or less? | Were key potential confounding variables measured and adjusted statistically for their impact on the relationship between exposure(s) and outcome(s)? | Summary Quality |
|--------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|----------------------------------------------------------------|-------------------------------------------------|----------------------------------------------------------------|-------------------------------------------------|----------------------------------------------------------------|-------------------------------------------------|----------------------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|
| Kim (2013)   | ✔                                               | ✔                                               | ✗                                               | ✔                                                               | ✔                                               | ✔                                                               | ✔                                               | ✔                                                               | ✗                                               | ✔                                                               | ✔                                                               | ✔                                               | ✗                                               | ✔                                               |
| Kim (2009)   | ✔                                               | ✔                                               | ✗                                               | ✔                                                               | ✔                                               | ✔                                                               | ✔                                               | ✔                                                               | ✗                                               | ✔                                                               | ✔                                                               | ✔                                               | ✗                                               | ✔                                               |
| Franciosi (2019) | ✔                                               | ✔                                               | ✗                                               | ✔                                                               | ✔                                               | ✔                                                               | ✔                                               | ✔                                                               | ✗                                               | ✔                                                               | ✔                                                               | ✔                                               | ✗                                               | ✔                                               |
| Lee (2015)   | ✔                                               | ✔                                               | ✗                                               | ✔                                                               | ✔                                               | ✔                                                               | ✔                                               | ✔                                                               | ✗                                               | ✔                                                               | ✔                                                               | ✔                                               | ✗                                               | ✔                                               |

### Appendix Table 2. The National Institute of Health (NIH) Quality Assessment Tool assessing the quality of studies included in the systematic review. Quality was rated as 0 for poor (0-4 out of 14 questions), i for fair (5-10 out of 14 questions), or ii for good (11-14 out of 14 questions).

NA, not applicable; NR, not reported.

### Appendix Table 3. Complications and adverse events

<table>
<thead>
<tr>
<th>Author (Year)</th>
<th>Complications/Adverse Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kim (&lt;40 degrees*, 2009)</td>
<td>Cortical break at fibular head requiring 6 more weeks of immobilization (n=1)</td>
</tr>
<tr>
<td>Kim (40-50 degrees*, 2009)</td>
<td>None.</td>
</tr>
<tr>
<td>Kim (&gt;50 degrees*, 2009)</td>
<td>None.</td>
</tr>
<tr>
<td>Kim (2012)</td>
<td>Reoperation (n=1); ROM Deficit (n=3); osteoarthritis progression (n=1)</td>
</tr>
<tr>
<td>Kim (single bundle, 2011)</td>
<td>Cortical break at fibular head requiring 6 more weeks of immobilization (n=1)</td>
</tr>
<tr>
<td>Kim (double bundle, 2011)</td>
<td>None.</td>
</tr>
<tr>
<td>Kim (anatomic reconstruction, 2011)</td>
<td>Cortical break at fibular head requiring 6 more weeks of immobilization (n=1)</td>
</tr>
<tr>
<td>Kim (rerouting biceps tendon, 2011)</td>
<td>Nerve damage (n=1); Reoperation (n=2)</td>
</tr>
<tr>
<td>Franciozi (2019)</td>
<td>Infection (n=1); Reoperation (n=1); Arthrofibrosis requiring MUA (n=4); Patellar fracture (n=1)</td>
</tr>
<tr>
<td>-----------------</td>
<td>-------------------------------------------------------------------------------------------------</td>
</tr>
</tbody>
</table>

*, represents the degree of tibial external rotation at 90 degrees of knee flexion
Records identified from PubMed, Embase, MEDLINE, Cochrane Library: 17,094

Records removed before screening:
- Duplicate records removed (n = 6,822)
- Records marked as ineligible by NOT human study or English translation (n = 113)

Records screened (n = 10,159)

Records excluded via Abstract Screening (n = 10,077)

Reports sought for full-text retrieval (n = 82)

Reports not retrieved (n = 7)

Reports assessed for eligibility (n = 75)

Reports excluded:
- Unable to separate outcomes scores (n = 51)
- Acute PLC injuries (n = 12)
- Less than two-year follow-up (n = 6)

Studies included in review (n = 6)
Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐ The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: